

Growth Performance and Adaptive Strategy of Early Seedlings of Three Savanna Woody Species in Pots as Feedback to the Soil of Macrotermes Subhyalinus Mound

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Abstract

Heterogeneous physiognomy and observed diversity of woody vegetation in savanna are considered as specific responses of seedling species during their growth to the given site characteristics changeable with time. Consequently, understanding early plant attitude using different growth soil is an important indicator in choosing species to introduce or to assist natural or artificial regeneration to the extent that establishment and productivity of plant species are not solely controlled by the effects of habitat modification and/or environmental resource availability but mostly by seedling quality. This study focused on comparative assessment of growth performance and adaptive traits of early seedlings of *Balanites aegyptiaca*, *Diospyros mespiliformis* and *Tamarindus indica* three multipurpose species between of *Macrotermes subhyalinus* mound and surrounding area in order to understand the attitudes of woody species hosted by termite mounds. Seedlings of similar age per species were grown in plastic bags as pots containing composite soils sampled till a depth of 30 cm on mounds and surrounding area in Tiogo state forest and of which the amount of retained water, carbon (C), nitrogen (N), calcium (Ca), magnesium (Mg), assimilable phosphorus (ass. P) and potassium (K) were quantified prior to growth experiment. Height and collar diameter of seedling stems, final length and diameter of the main root were measured; the total dry biomass of root and shoot and, root to shoot ratio were evaluated for seedlings up to 5 months relating to the soil origin. Mean values of retained water and

selected nutrients were higher for mound soil than for surrounding soil. Besides, the studied parameters of *T. indica* seedlings were significantly higher for mound soil than those recorded for surrounding soil ($P < 0.05$) whereas seedlings of *B. aegyptiaca* and *D. mespiliformis* exhibited an increase final stem collar diameter and main root length on mound soil ($P = 0.039$ and 0.028 respectively). Root to shoot ratio of *B. aegyptiaca* seedlings was positively correlated with great N content and that of *D. mespiliformis* seedlings with great concentration of Ca. Growth performance and adaptive traits of early seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* were remarkable on M. subhyalinus mound soil compared to surrounding soil relating to the great level of soil fertility. Therefore, understanding the attitude of woody seedlings of local or exotic species is an important key in global plantation programs or assisting natural regeneration for biodiversity management and conservation.

Keywords: Burkina Faso, Multipurpose tree, Savanna regeneration, Seedling biomass, Soil macronutrients, Termitaria

Introduction

Heterogeneity in morphological features, growth and biomass production of woody species can be considered as cumulative outcomes of ecological processes that inherently vary in time and space (Lovett *et al.*, 2005). This heterogeneity is more striking in African savannas as response to intensity gradient of these ecological processes which ultimately can positively or negatively impact the performance of woody species to colonize given ecosystems and/or the mechanisms that each species can develop to adapt to. Positive or negative impact of ecological processes can be expressed by selecting suite traits of species that control seedling establishment and thereby seedling recruitment into saplings, and later into mature trees in vegetation community (Solbrig, 1994). Among the ecological processes in arid and sub-arid savannas, soil processes and habitat modification are well known and documented as the major factors responsible of the availability and patchiness of environmental resources allocation locally redistributed which in return cause the mosaic dynamic, structure, composition and assemblage of woody species (Menaut *et al.*, 1995). Environmental resources such as soil moisture, soil carbon (C) and nutrient as nitrogen (N), calcium (Ca), potassium (K) magnesium (Mg), and assimilable phosphorus (ass. P) play a fundamental role in growth and development of the shoot and root systems of woody seedlings, and other biological processes thereby shape competitive interaction between species for colonizing various microhabitats (Ericsson, 1995; Taiz & Zeiger, 2006; Chmelíková & Hejčman, 2012; Gil *et al.* 2012; Tanoi & Kobayashi, 2015). As consequent, sustained growth and efficient

recruitment of seedling species, specific physiognomy of woody vegetation and by afar, biodiversity stability and resilience through propagation of stems of the same species are deeply correlated with optimal soil moisture and nutrient content in savanna ecosystems (Wiens, 1985; Bloom *et al.*, 1985; Solbrig, 1994; Day *et al.*, 2003; Clarke *et al.*, 2005).

Microhabitats built by ecosystem engineers as *Macrotermes* sp workers as soil processes and habitat modification strongly alter the availability, patchiness and concentration of soil nutrients and stored water duration. In the course of their foraging and building activities, workers of *Macrotermes subhyalinus* Rambur (Termitidae, subfamily Macrotermitinae) directly or indirectly rearrange huge amounts of soil, in which they concentrate nutrient content deeply improved and stock in form of mounds above soil surface commonly considered as “heterogeneity drivers” (Holt & Lepage, 2000; Moe *et al.*, 2009; Jouquet *et al.*, 2011; Muller & Ward, 2013; Davies *et al.*, 2016). Such fertile microhabitats scattered and available in savanna contribute to enhance safe ecological niches for plant species and for other organisms, and as rooting niche in where varied woody species occur, establish, develop and coexist for creating termite mound savanna despite species biogeographical origin as Sudanian, Guinea or Sahelian species and ecophysiological characteristics as fire sensitive species (Mobæk *et al.*, 2005; Moe *et al.*, 2009; Fandohan *et al.*, 2012; Okullo & Moe, 2012). Such microhabitats likely seem to provide fundamental attribute to seedlings of these woody species and then facilitate their establishment and recruitment into mature trees as specific response. By acting so, they may involve certain species to be favoured under different circumstances depending on the factors that can limit their morphology, productivity and, on the way of which these species can recover from and grow for becoming microhabitat indicators. This is the case of certain woody species hosted by termite mounds solely as indicatory flora including fire and herbivory sensitive or tolerance species or as annual or perennial species (Dossou-Yovo *et al.*, 2009; Moe *et al.*, 2009; Zida *et al.*, 2009; van der Plas *et al.*, 2013; Joseph *et al.*, 2014). In parallel, woody species use to regenerate, survive and colonize disturbed or undisturbed microhabitats, and adapt to them through varied morphological and specific traits as vigorous root systems as net primary production. For example, woody species can increase their root biomass for escaping injurious of ecological interactions in savanna according to Zida *et al.* (2009) while they exhibit high relative growth rate as clue of sustained rapid growth of stem height in nutrient-rich habitat compared with nutrient-poor habitat (Chapin III, 1980). As regarding these previous results, the recruitment and survival of plants in field depend not solely on the top soil quality but mostly on the seedling quality such as stem and roots growth ability, biomass productivity during early seedling growth and the mechanisms they can use for taking root

and recovering post disturbance. Works led by ecologists (Joseph *et al.*, 2011; Jouquet *et al.*, 2011; Muller & Ward, 2013; Støen *et al.*, 2013; Traoré *et al.*, 2015) in various ecosystems showed that *Macrotermes* sp mounds hosting vegetation act for woody species as refuges under fire and livestock disturbances, water runoff events and, as regeneration facilitators due to their profile of elevated and fertile structures respectively. However, those discussing the ability of woody species and the mechanisms they use to become established, and grow to sapling and tree with emphasis on the attitude of seedlings on termite mounds in comparison with surrounding savanna in experimental designs are poorly or non-documented. It is in this optic that the present study was carried out for contributing to provide information on physiological attitude of wild multipurpose species that grow on epigeal termite mounds.

The objective of this work was to study whether woody species develop particular traits at seedling stage as feedback prior to establish, adapt to and grow on mounds of *M. subhyalinus* or not. To test this we quantified the growth performance of shoot system and the developed adaptive attributes of early seedlings in experimental pots using soil samples from *M. subhyalinus* mounds and surrounding area in a state forest. The results of growth assessment of early plants may improve our knowledge on the ability of viable propagules to establish on epigeal termite mounds and serve as guide in choosing species to introduce or assist natural regeneration in field for the target of biodiversity management and conservation considering given area characteristics as agroforestry or forestry. We specifically (1) compared moisture and nutrient content between soils of *M. subhyalinus* mound and corresponding surrounding area (as control); (2) assessed for each cohort on each site soil as growth features, the height and collar diameter of each stem and, the final length and diameter of the main root of each seedling as adaptive attribute; (3) examined the relationship between the total weight of dry biomass of root and shoot for each cohort and (4) tested whether the weight of dry root biomass over that of dry shoot biomass was related to the great soil nutrient content or not. Our findings could contribute to suggest another insight into the ability of certain woody species to be restricted to termite mounds or particular microsites although they are naturally growing in their ecological and geographical borders. We assumed that the growth performance and adaptive traits of early seedlings of *Balanites aegyptiaca* (L.) Del., *Diospyros mespiliformis* Hochst. Ex A.D.C. and *Tamarindus indica* L. are specific as feedback to *M. subhyalinus* mound in savanna ecosystems of which local residents depend on provided services and goods for their livelihood (von Maydell *et al.*, 1990).

Materials and methods

The study materials included seedlings of three multipurpose woody species of West African savanna ecosystems and soil samples collected on vegetated *M. subhyalinus* mounds and surrounding savanna in the sub-plots protected from prescribed fire regimen and livestock grazing settled in Tiogo state forest (Traoré *et al.*, 2015). We focused on the soil of the large mounds occupied by the fungus-growing termite as *M. subhyalinus* due to its large influence on soil water infiltration, nutrient turnover, and on woody species assemblage in this ecosystem. The surrounding area or surrounding savanna in this study refers to the area being out of the visible influences of termite species such as foraging tunnel or sheeting.

Study species description

Species as *Balanites aegyptiaca* (L.) Del., *Diospyros mespiliformis* Hochst. Ex A.D.C. and *Tamarindus indica* L. involved in this study were selected among the numerous woody species identified on termite mound savanna (Traoré *et al.*, 2008a, 2015; Erpenbach *et al.*, 2014) to study the attitude of seedlings growing on *M. subhyalinus* mound in comparison with those growing in the surrounding savanna. *B. aegyptiaca* (Balanitaceae), a Sahelian species is drought and fire resistant and withstands up to 2 months flooding in areas near the river. It occurs on sandy clay loams, sandy loams or clays and prefers open woodland or savanna for natural regeneration.

D. mespiliformis (Ebenaceae), a Sudanian species prefers areas with permanent water that helps in natural regeneration. It favours heavy soils on riverbanks, in woodlands, savannahs and along riverbanks but also occurs in open woodland and is commonly found on termite mounds.

T. indica (Caesalpiniaceae), a Guinea species tolerates a range of soils but it prefers a well-drained, fertile soil. It occurs on coast and in sandy soils, on riverbanks, in savanna woodland, and is commonly related to termite mounds. *T. indica* seedlings and saplings are killed during fire event in savanna.

B. aegyptiaca, *D. mespiliformis* and *T. indica* are multipurpose tree species characterized by different ecological properties and are ecologically, socio-economically and socio-culturally used for ecosystem services and also as ecosystem goods respectively (von Maydell *et al.*, 1990; Arbonnier 2000; Nikiéma 2005, Weber & Montes, 2010; Orwa *et al.*, 2009; Sanou *et al.* 2012; Aladi & John, 2014). The natural populations of these woody species are experiencing higher pressure as consequences of increase demands as livestock overgrazing, fuel requirement, and extensive cultivation and the injurious effects of climate caprices (scarcity and abnormal seasonal distribution of rains) that cause a decline of the natural stands and regeneration. Recent reports have underlined that *M. subhyalinus* mounds shelter great density of mature trees and seedlings of these multipurpose

species while the surrounding savanna solely shelters great density of juvenile stems of the same species (Abbadie *et al.*, 1992; Traoré *et al.*, 2015). The survival of seedlings and saplings was strongly reduced out of mounds due to the damage caused to them by abiotic and biotic factors during vulnerable stage in opened ecosystems.

Sampling and properties of the study soils

The soils used for plant growing were sampled in the Tiogo state forest located between 12°13' - 12°24' N and 2°42' - 2°52' W, at an altitude of 300 m a.s.l., in the Centre West of Burkina Faso, West Africa. This state forest is characterized by ferruginous lxisols with deep silty-clay mainly (> 75 cm deep) according to Driessen *et al.* (2001). The main characteristics of the soil in this forest were clay (24.8 %), fine silt (15.0 %), coarse silt (25.4 %), fine sand (21.7%), coarse sand (13.1 %), total organic matter (1.8 %), total nitrogen (0.1 %), C/N ratio (11.4 %), assimilable phosphorus (1.4 ppm) and pH (H₂O) (6.2) (Sawadogo *et al.*, 2005).

Soil bulks were directly sampled between 0 - 30 cm depth on mound-top, or dome, mound-slope and mound-base, and surrounding area (as control soil) as growth media in experimental quadrats described in Traoré *et al.* (2015).

Physical and chemical properties of each site soil were identified prior to set growth experiment. Soil moisture as soil water content was measured using soils sampled from mounds and surrounding area through two sampling methods in relation to the ability of seedlings to survive on each soil during their growth.

First method consisted to collect soil samples directly in the field during the rainy season in order to evaluate the variation of water storage duration. For this purpose, composite soil samples were taken with sterilised boxes three times at t0, t1 and t2 corresponding to 0 (rainy day), 2 and 4 days respectively after raining. The sampling operation was interrupted at a following rainy event.

Second method consisted to collect soil samples at fixed weight of 105g after open air drying, with sterilised boxes and watered with fixed volume of 210 ml each.

The fresh weight (FW) was measured for each soil samples according to sampling methods before drying them in oven at 105°C at constant weight for 4 days. The dry weight (DW) was then measured and water content (W) as soil relative moisture was calculated as a percentage of the dry soil weight using the following formula:

$$W\% = \frac{(FW - DW)}{DW} * 100$$

Chemical components were quantified at “Bureau National des Sols (BUNASOLS)” a national laboratory in charge of the physical and chemical analysis of soils in Burkina Faso. The amount of total organic C (TOC), and soil nutrient content such as total N (TN), and ass. P was quantified using the methods of Walkley & Black (1948), Kjeldahl (1883) and Bray n°1 extractant respectively and Ca, K, Mg (Bunasols, 1987). Nutrients as N, Ca, K, Mg and ass. P are provided solely by the soil or other growth media whereas C is obtained from water in which all nutrients are dissolved and available for plant roots uptaking in usable forms (Taiz & Zeiger, 2006; Tanoi & Kobayashi, 2015).

Description of experimental design

Soil bulks were crushed and mixed to constitute composite media, prior to fill perforated polythene black bags of 8 cm x 15 cm sized, with a volume of 2 litres of soil samples of mound and that of surrounding area and kept in the nursery. Three replicates per species and per growth medium were performed. The filled bags referring to pots were used to conduct this study in order to ecologically harvest entire root and shoot systems even if broken for a good biomass quantifying contrary to *in situ* grown, seedlings cannot be harvested without digging soil and, many fine roots can be broken and left in the soil.

Seedling emergence, growth and measurement

Seedlings were obtained after germinating the seeds of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* which were purchased from the National Centre of Forest Seeds (C.N.S.F), Burkina Faso. Maximum seeds were pre-treated with sulfuric acid (H₂SO₄) of concentrated of 60% for 20 minutes for breaking all eventual dormancy in order to have the requested number of seedlings of the same age. Seeds were then rinsed and kept in beaker filled up with tap water for 72 hours. After pre-treating, two germinated seeds with the primary root were directly sowed at 3 cm of depth in each pot for early growth assessment. All the pots were deposited under partial tree shade in the cells of metallic frame to avoid all contact with soil surface and watered twice per day in the morning and evening during the whole experimental period for maintaining the soil moisture conditions.

The height and collar diameter of single stem and multi-stem individuals were monthly recorded 4 weeks after complete emergence of stems for each cohort. After 4 months of growth survey for *D. mespiliformis* and 5 months for *T. indica* and *B. aegyptiaca*, all the seedlings were then harvested and their roots were carefully washed to remove all soil particles. The survey was interrupted at 4 months for *D. mespiliformis* because the root system of seedlings was growing through the plastic bags.

The final height and final collar diameter of each stem and, the length and diameter of the main root were recorded for each seedling species and growth medium. The measured root diameter corresponded to the average of three diameter values performed at the top, middle and tap-root because the main root of studied seedlings was showing varied width. Roots and shoots were separated and freshly weighted, dried in a hot-air oven for 2 days at 75°C. After that the dry weight of roots and shoots were recorded respectively.

Data analysis

Graphical and statistical methods were used to explore and analyse recorded data for soil and seedlings. The growth curves were generated to assess the monthly variation of stem height and collar diameter for the cohorts of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* for termite mound and surrounding soils.

The ratio of the weight of dry root biomass over dry shoot biomass was calculated for the total produced biomass for each cohort and each growth medium.

Univariate analysis (ANOVA) was performed to assess the effect of time, mound and their interactions on soil water content through method 1 on the one hand. Multiple comparison of mean values were carried out in case of significant effect. On the other hand Student's t-test was used to compare the mean values of water content in soil sampled through method 2. Student's t-test was also performed to compare between termite mound and surrounding soils the mean values of soil nutrient content, stem final height and collar diameter, root to shoot ratio within species (Underwood, 2002). Pearson's correlation was performed to examine relationship on the one hand between organic matter (TOC and TN) and nutrient content in each soil and, on the other hand between the weights of seedling dry biomass (root and/or shoot) and soil nutrient content.

All the statistical analysis were performed at 5% of significance with equal variances assumed using SPSS 20 for Windows.

Results

Physical and chemical properties of the soil samples

The results of physical and chemical properties of soil samples issue from *M. subhyalinus* mound and surrounding savannas are summarized and given in Table 1. The mean values of water content was higher for mound soil than surrounding soil through both of methods 1 and 2. These values moderately decreased with time (method 1) while remaining higher for mound soil (Table 1).

The univariate analysis revealed no significant difference in stored water content over evaluation time and/or soil origin ($F = 0.749$, $P = 0.590$)

when method 1 was applied, and Student's t-test statistically also reported no difference in water content between termite mound and surrounding soils ($P > 0.05$) (Table 1). Conversely, mound soil contained considerably percentages of C, N, Ca, K, Mg and ass. P in relation to surrounding soil (t-test, $P < 0.05$) whereas no statistical difference was observed for C/N ratio between soil samples ($t = 0.69$, $P = 0.499$) (Table 1).

Table 1. Comparison of mean values (\pm standard deviation) of the amount of (A) stored water W and, (B) organic C and nutrients between *M. subhyalinus* mound and surrounding soils.

	Mound soil	Surrounding soil	df	F	t	P
(A) Relative water content W (%)						
Method 1						
Day 0	12.25 \pm 6.37	10.05 \pm 6.46				
Day 2	10.76 \pm 5.66	9.48 \pm 7.56	-	0.749	-	0.59
Day 4	10.35 \pm 7.26	9.46 \pm 7.04				
Method 2	19.33 \pm 3.92	18.65 \pm 3.08	33	-	0.56	0.33
(B) Chemical property						
Total organic C %	2.73 \pm 0.91*	1.54 \pm 0.94	21	-	3.04	0.006
Total N %	0.22 \pm 0.08*	0.12 \pm 0.06	21	-	3.50	0.002
C/N %	12.98 \pm 2.15	12.20 \pm 3.01	21	-	0.69	0.499
Ca (Cmol.Kg ⁻¹)	11.51 \pm 4.06*	4.70 \pm 4.26	21	-	3.88	0.001
K (ppm)	1.41 \pm 0.56*	0.45 \pm 0.30	21	-	5.10	0.0003
Mg (Cmol.Kg ⁻¹)	4.26 \pm 1.33*	2.25 \pm 1.65	21	-	3.16	0.005
Ass. P (ppm)	6.62 \pm 2.95*	1.98 \pm 1.55	21	-	4.90	0.0001

* Significant at $P < 0.05$ with equal variances assumed

The analysis of Pearson's correlation showed positive relationship between soil nutrient and TOC, TN percentage as has been shown in Table 2. The great amount of Ca was highly correlated with the great percentage of TOC ($P < 0.001$), and Mg content was strongly correlated with the great percentage of TOC and TN ($P < 0.05$) in mound soil; Pearson's correlation was highly significant between ass. P and Ca contents in mound soil ($P < 0.001$) and weakly in surrounding soil ($P < 0.05$). At the opposite side, the amount of soil Ca ($P < 0.001$) and, Mg and ass. P ($P < 0.05$) were significantly related with TOC and TN, Mg and ass. P content were correlated with Ca content in the surrounding soil samples (Table 2).

Table 2. Variation of the coefficient value of Pearson's correlation between the amount of, TOC and nutrient contents for the soils of (A) *M. subhyalinus* mound and (B) surrounding area.

	TN %	TOC %	C/N %	Ca (Cmol.Kg ⁻¹)	Mg (Cmol.Kg ⁻¹)	ass. P (ppm)	K (ppm)
(A) Mound soil							
TN %	1						
TOC %	0.857**	1					
C/N %	-0.530	-0.050	1				
Ca (Cmol.Kg ⁻¹)	0.531	0.702**	0.005	1			
Mg (Cmol.Kg ⁻¹)	0.850**	0.936**	-0.097	0.528	1		
ass. P (ppm)	0.130	0.496	0.415	0.834**	0.334	1	
K (ppm)	-0.439	-0.440	0.189	-0.062	-0.549	0.083	1
(B) Surrounding soil							
TN %	1						
TOC %	0.980*	1					
C/N %	0.580*	0.725**	1				
Ca (Cmol.Kg ⁻¹)	0.852**	0.803**	0.370	1			
Mg (Cmol.Kg ⁻¹)	0.982*	0.962*	0.561*	0.884*	1		
ass. P (ppm)	0.838*	0.873*	0.681*	0.604*	0.826*	1	
K (ppm)	-0.198	-0.072	0.471	-0.199	-0.133	-0.256	1

*Correlation is significant at $P < 0.05$; **Correlation is highly significant at $P < 0.001$.

Growth performance of seedlings

The Figure 1 based on the monthly measurement presents the variation of seedling height and collar diameter within species and over time. Height and collar diameter of stem of the cohort per species were unequally distributed during the survey periods and according to growth soil origin. Conversely, within species, the monthly mean value of stem height and collar diameter of *B. aegyptiaca* and *T. indica* seedlings constantly increased for termite mound soil compared with surrounding soil whereas stem height and collar diameter of *D. mespiliformis* seedlings increased solely on surrounding soil (Figure 1).

Moreover, the values of monthly rate of relative growth of stem height and collar diameter of the seedling cohorts varied remarkably in response to soil origin during the survey period. Great value was observed for seedlings height of *B. aegyptiaca* (51.27 %) and diameter of *B. aegyptiaca* (40.47 %) and *T. indica* (39.71 %) seedlings on mound soil (Table 3). For *B. aegyptiaca* seedlings the growth rate of stem height on mound soil was 1.35 and 1.17 times those recorded on surrounding soil at the first 2 and last months of survey and, the collar diameter was threefold and 6 times at the same period.

As showed in Table 3, an increasing in stem height was observed for *D. mespiliformis* seedlings solely on mound soil at the first two months (32.84 %) while the collar diameter constantly increased on surrounding soil. Increase values of relative growth rate of stem height was observed for the seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* (except for surrounding soil) at the end of survey meaning a remarkable growth of stem height with suit

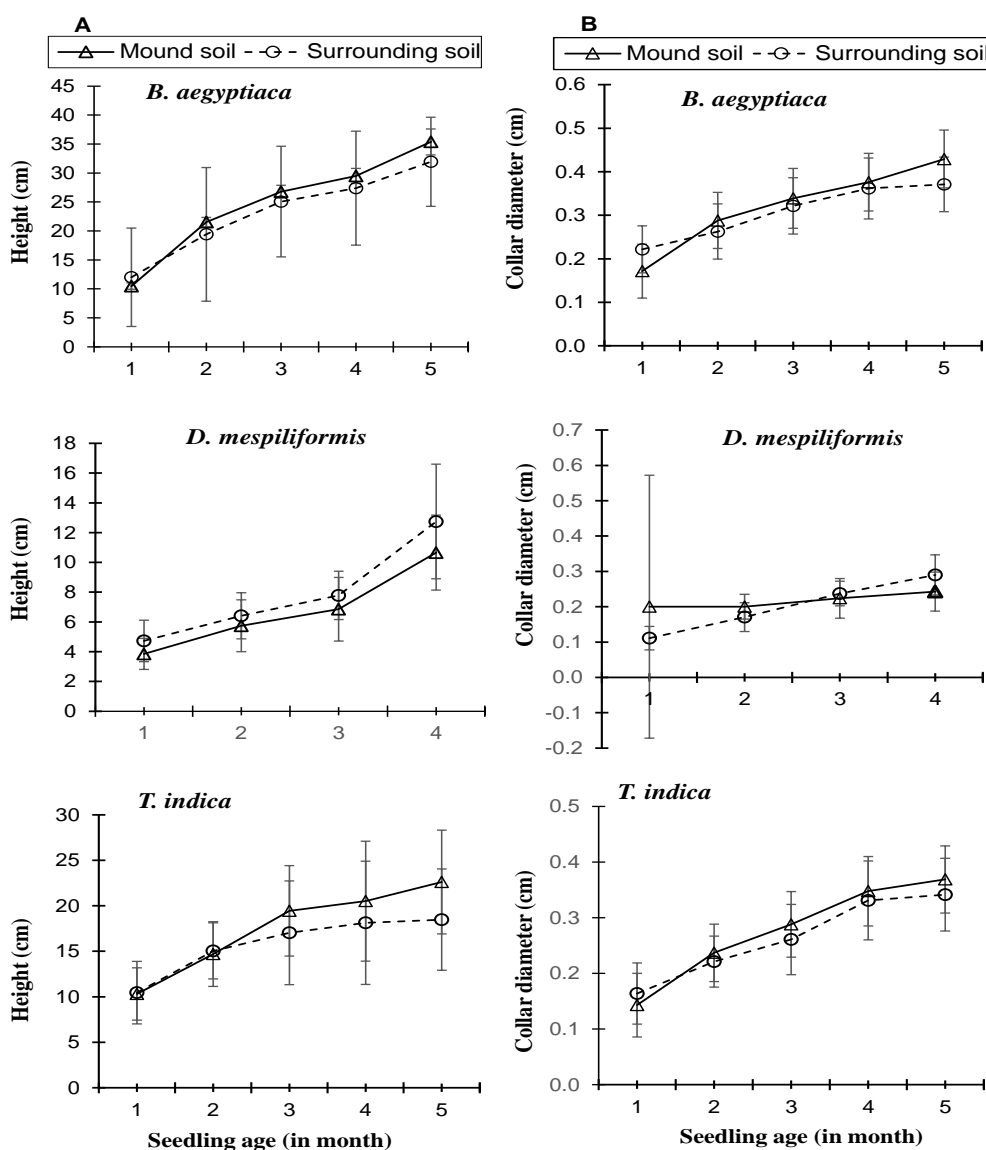


Figure 1. Distribution of mean values (\pm standard deviation) of height (A) and collar diameter (B) of tree seedlings growing on the *M. subhyalinus* mound soil and surrounding soil.

Table 3: Variation of the monthly rate of relative growth of the stem height and collar diameter of seedlings per species on the *M. subhyalinus* mound and surrounding soils.

Seedling species	Soil origin	Stem height (%)				Stem collar diameter %			
		Seedling age (in months)				Seedling age (in months)			
		2	3	4	5	2	3	4	5
<i>Balanites aegyptiaca</i>	Mound soil	51.27	19.61	9.20	16.67	40.47	15.01	9.88	12.36
	Surrounding soil	38.11	22.56	8.51	14.23	15.55	18.27	11.14	2.13
<i>Diospyros mespiliformis</i>	Mound soil	32.84	16.28	35.7	-	0	10.59	7.89	-
	Surrounding soil	26.32	17.64	38.97	-	34.92	28.05	18.18	-
<i>Tamarindus indica</i>	Mound soil	29.81	24.41	5.17	9.29	39.71	17.77	17.14	5.72
	Surrounding soil	30.52	11.66	6.06	1.89	25.91	15.21	21.25	3.02

Student's t test revealed that the final values of height and collar diameter of stem, the length and diameter of the main root of *T. indica* seedlings were significantly higher for mound soil than surrounding soil ($P < 0.05$) (Table 4). The mean values of the final collar diameter of stem of *B. aegyptiaca* seedlings growing on mound soil significantly increased ($P = 0.039$) while *D. mespiliformis* seedlings exhibited significant long main root on mound soil ($P = 0.028$) as compared with those growing on surrounding soil.

According to the values of root to shoot ratio in Table 4, the weight of seedling dry roots were equivalent to 1.69, 1.07 and 1.41 the weight of dry shoot system on mound soil for *B. aegyptiaca*, *D. mespiliformis* and *T. indica* respectively. But no significant difference in the ratio value of dry root over dry shoot biomass between soils (t-test, $P > 0.05$) indicating similar ratio values.

The correlation analysis of Person showed that the ratio value of dry root over dry shoot biomass of *D. mespiliformis* seedlings was positively correlated with the great amount of Ca contained in both of mound and surrounding soils (mound soil, coefficient = 0.999; $P = 0.024$ and surrounding soil, coefficient = 0.998; $P = 0.031$) whereas the ratio value of dry root to dry shoot biomass of *B. aegyptiaca* seedlings was significantly correlated with the great amount of TN of mound soil only (coefficient = 0.980; $P = 0.020$).

More, the root systems of seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* growing on *M. subhyalinus* mound soil showed countless fine roots or root hairs in comparison with those of seedlings on surrounding soil (Figure 2). But the root system of seedlings of *T. indica* was more ramified growing on mound soil comparatively with that of seedlings of the same species on surrounding soil.

Table 4: Variation of the mean values (\pm standard deviation) of the final stem height, collar diameter, main root length and diameter and root to shoot ratio of the dry biomass weight of seedling cohorts for each species growing on the *M. subhyalinus* mound soil and surrounding soil.

Seedling parameters	<i>Balanites aegyptiaca</i>			<i>Diospyros mespiliformis</i>			<i>Tamarindus indica</i>		
	Mound	Surrounding	<i>P</i>	Mound	Surrounding	<i>P</i>	Mound	Surrounding	<i>P</i>
Final stem height (cm)	35.38 \pm 11.18	31.94 \pm 7.69	0.41	10.66 \pm 2.51	12.75 \pm 3.85	0.93	22.61 \pm 5.70*	18.48 \pm 5.56	0.005
Final collar diameter (cm)	0.43 \pm 0.07*	0.37 \pm 0.06	0.039	0.24 \pm 0.06	0.29 \pm 0.06	0.48	0.37 \pm 0.06*	0.34 \pm 0.07	0.0001
Main root length (cm)	28.52 \pm 10.37	24.93 \pm 8.65	0.056	36.79 \pm 14.68*	26.90 \pm 12.65	0.028	41.55 \pm 15.65*	32.88 \pm 13.61	0.001
Main root diameter (cm)	0.30 \pm 0.07	0.27 \pm 0.07	0.93	0.22 \pm 0.11	0.23 \pm 0.12	0.67	0.27 \pm 0.06*	0.22 \pm 0.06	0.0007
Root-shoot ratio	1.69 \pm 1.13	1.38 \pm 1.03	0.47	1.07 \pm 0.89	0.33 \pm 0.21	0.52	1.41 \pm 0.75	1.31 \pm 0.54	0.744

* Significant at $P < 0.05$ with equal variances assumed; *P*: Probability

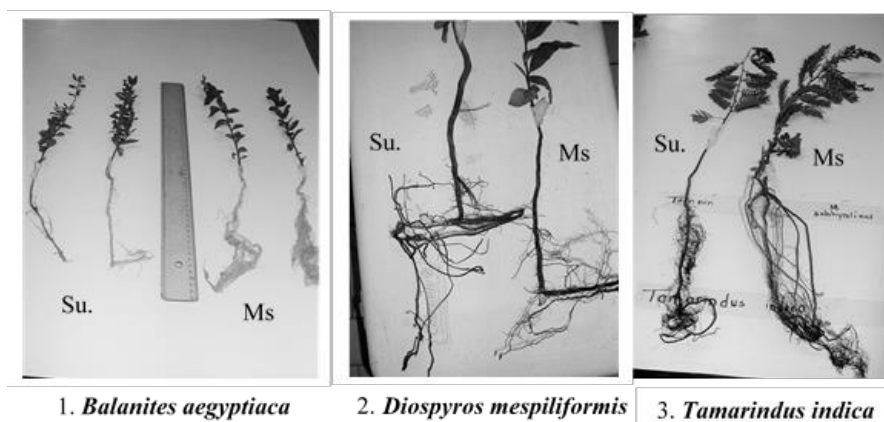


Figure 2: Comparison of the seedlings resulting from the soil of *Macrotermes subhyalinus* mound (Ms) and surrounding soil (Su.)

Discussion

The present study quantified and compared the growth performance and adaptive strategies of early seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* through their morphology and biomass production using *M. subhyalinus* mound soil in order to understand whether woody species develop particular traits at seedling stage as feedback prior to establish and colonize epigeal termite mounds. Changes were observed for seedling cohort of each species which changes tend to be as specific feedback to *M. subhyalinus* modulated soil in comparison with “intact” soil collected from the surrounding area. Although the absence of significant difference in water content between growth soil samples, the mean values of stored water content remains higher for *M. subhyalinus* mound soil as compared with surrounding soil along the time spectrum. This likely may be due to the general structure of soil in Tiogo forest which has influenced water content of study soil samples at soil level and time level as regarding the great values of the standard deviations. The great percentage of soil stored water may be explained by the predominance of finer sized particles used for mound building and also found in the original savanna soil in Tiogo forest (Sawadogo et al., 2005; Pallo et al., 2009; Traoré et al. 2015). On contrary to water content which is statistically similar, mound soil contained significant great amounts of TOC, TN and nutrients as Ca, K, Mg and ass. P. Nutrient concentration also increase with that of TOC and TN according to Pearson’s correlation test. The amount of TOC and TN may result from termite wastes combined with great organic matters resulting from dead termites and other dead organisms such as hedgehog, rodent, gecko that seem to be accumulated in mound cavities and from fallen leaves and decayed roots (as litter layer) of plants growing in mound savanna (Traoré et al., 2015) whereas the release nutrients may result from soil microbial activities as

reported by Duponnois et al. (2005). As they accumulate in soil, C and N act as traps for nutrients and by this way they retain nutrient in form of salts in soil and thereby increase mound fertility at low cost. Consequently, the higher the percentage of TOC and TN in the soil, the higher the nutrient concentration. The positive association that exists between nutrients and, TOC and TN justify the fact that *M. subhyalinus* mounds are considered as small macronutrients reservoirs or “hot-spots” macronutrients (Holt & Lepage, 2000) scattered in savanna ecosystems. These small reservoirs of macronutrients play key role in the functioning and pattern of plant communities during succession steps from pioneers to climax.

The studied parameters of *T. indica* seedlings except the dry biomass of root/shoot, stem collar diameter of *B. aegyptiaca* and the length of main root of *D. mespiliformis* seedlings significantly increased on soil samples of termite mound. The great value of monthly relative growth rate indicate rapidly increase for each species cohort on mound soil at the beginning of measurement. Increase of these morphological traits of seedlings on mound soil may certainly be due to a constant production of new body tissues further to regular uptake of great nutrient content available in the usable forms and stimulated by long main root and numerous associated fines roots that seedlings developed during their growth (Taiz & Zeiger, 2006). Such fines roots seems to have increased the root surface of absorption and therefore, strengthen seedling proficiency to acquire soil water and nutrients on mounds for maximizing seedling growth or promoting their regrowth after drought injurious according to Bloom et al. (1985). Contrary to surrounding soil, fine root proliferation and root growth of seedlings were reduced relating to weak nutrient availability.

No significant difference was observed in the values of root to shoot ratio in relation to growth soil origin indicating that the study species have similar weight of dry roots over dry shoots wherever they can grow. Nevertheless, the weight of dry root slightly exceeds that of dry shoot biomass of seedlings leading to consider that seedling species belong to the same biological life growth form as woody or perennial species of which the values root to shoot ratio are specific. Work carried out by Monk (1969) on the relationship between above and underground parts of 15 plant species reported that the higher values of root to shoot ratio (root/shoot >1) are considered as indicators of perennial woody and plant species adapted to dry site.

The present results corroborate previous reports on the relationship between plants and their growth site. It seems that when soil nutrients get lower as observed for soil from surrounding savanna, the growth of plant species get reduce or interrupt. Therefore, seedlings to a certain extent juvenile plants get to adapt their demands for nutrients in response to a decline of soil solution caused by drought stress. Throughout establishment, the great rate of

relative growth of *T. indica* seedlings and the long root of *D. mespiliformis* can ensure for them a competitive benefit when seedlings of these species are grown together with other plant species in the diversified microhabitats (high species diversity) as mounds of *M. subhyalinus* (Joseph et al., 2014; Davies et al., 2016) or microhabitats presenting similar physical and chemical properties. The development of the collar diameter subsequently the root system seems primordial for the study woody species to anchor and stock mineral resources for escaping damage when environmental conditions and soil moisture are suitable.

Regarding the increase size of aerial and underground systems during early growth of seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* in experimental design, we may certify that the proliferation of fine roots, maximizing root growth, and root biomass may constitute the adaptive strategies for seedlings as feedback to mound soil quality. Moreover, recruitment of seedlings into saplings and mature individuals may be interrelated to the constant increase of stem height and collar diameter as suit growth performance for most woody species growing on large termite mounds or some particular microhabitats else.

Conclusion

According to our results, there is evidence that early seedlings of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* or other woody species have a good growth performance while develop particular traits as feedback prior to establish and grow on *M. subhyalinus* mounds as compared with the surrounding soil and so, in relation to TOC and soil nutrient content in mounds. The survey of the growth and development of seedlings of similar age of *B. aegyptiaca*, *D. mespiliformis* and *T. indica* showed a progressive increase of stem height and collar diameter that indicate suitable growth performance on *M. subhyalinus* mound soil samples as advantageous for seedlings to escape intra- and/or interspecific competition events and environmental factors injurious in savanna ecosystems. The present study showed that most woody species can adapt their morphology and functioning, and develop strategies to survive, coexist, and grow for becoming indicators of termite mounds. By this way they thereby generate a nutrient-rich savanna to the detriment of the less competitive species although they are growing in or outside their geographical borders. For this reason, understanding the attitude of woody seedling of local and/or exotic species is an important key for their domestication or assisting natural regeneration at small or large scale in ecosystem restoration and, biodiversity management and conservation regarding the given microhabitat characteristics as rooting niches.

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